Three-Dimensional Rendering and Image Analysis of Coronal Loops

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In MSFC's Solar Physics Branch, research is conducted on solar magnetic fields and their physical associations and effects in the photosphere, corona, and interplanetary medium. Extensive efforts have been carried out in relating the MSFC vector magnetograms to flare theories. This research is extremely useful in that it describes the observed coronal magnetic structures in the solar atmosphere in relation to the observed photospheric magnetic field on the solar surface. The photospheric field is derived from the unique MSFC solar vector magnetograms. Using these data and observed x-ray images of the Sun, researchers are developing general data-analysis tools to be used to analyze soft x-ray images. The research objective is to be able to define the available free energy via the three-dimensional magnetic- and electric-current morphology transversing through the solar atmosphere.

The research includes the development of software that will display pseudo soft x-ray images given magnetic field lines, density, and temperature. The development process is as independent of specific models as possible to allow for many models in the final version. Crucial is the ability to provide an efficient computer algorithm that renders a three-dimensional volume into a two-dimensional image with adequate quality compatible for analysis and comparison with observations (e.g., from the soft x-ray telescope/Yohkoh). The code will provide a systematic comparison between (1) observed coronal flux tubes and models and (2) coronal flux tubes and their photospheric footpoints. Using existing codes and scaling laws to determine the coronal density and temperatures, and an instrument response code, one can theoretically determine the observed emission characteristics for each volume cell (voxel). Given this and some magnetic-field configuration (e.g., from a potential field or force-free field), the problem is one of integrating along the line of sight and displaying the resulting image. This problem is being addressed. A reasonable volume could have a million voxels, and an associated brightness must be calculated at each cube. Here, efficiency is the key point for the extensive volume-rendering programs. Having the brightness values, the code must integrate the semitransparent solar plasma and display the results in various graphic formats. This analysis package is of paramount importance in the research. The backward interpretation can begin—that is, having a two-dimensional image, the three-dimensional configuration can be inferred, and further studies of coronal temperatures, emission characteristics, field modeling, footpoint, and photospheric correspondence will proceed.

The description of the coronal magnetic field is a key component in understanding solar activity. Hence, this topic is in direct support of flight- and ground-based vector magnetograph programs which are specific NASA programs and a focus of the activities of the MSFC Solar Science Branch. The results are of particular significance to the mechanisms of solar variability and spaceborne magnetograph programs aimed at understanding the physical cause of variations in and from the Sun. The free magnetic energy that drives much of the variation is directly connected to the magnitude of the electric currents and heating in the solar atmosphere. To understand the dynamics of the x-ray imagery (e.g., from Yohkoh), one needs also to understand the electric currents (the source of energy) and the coronal configuration. The general analysis of the magnetic structures and their associated electric-current systems will discriminate between contending theoretical models. There is clearly a need for this analysis, as it relates to observations and reduced and analyzed data from the MSFC vector magnetograph and the development of the next-generation solar-orbiting instruments.

The research program is developing a formal basis for deriving and investigating solar magnetic structures and obtaining a better physical understanding of these results. MSFC magnetograms will be analyzed extensively to characterize the photospheric magnetic fields. The specific strength of this research is that the scientific investigation continues a strong program by the Solar Physics Branch in the area of magnetic field analysis. These studies are of the highest scientific merit to solar physics and are fundamentally important to the NASA Space Physics Program. The objectives are assured through a thorough technical approach. The relevance of the work lies in the deeper understanding it will provide of the processes underlying the observed structure of solar active regions, which are the main contributors to solar variability in ultraviolet and x rays.

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